TTI: 0-6143

MASH Test 3-11 of the TxDOT Portable Type 2 PCTB with Sign Support Assembly

ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Research/Test Report 0-6143-1

Cooperative Research Program

TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/0-6143-1.pdf

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-11/0-6143-1		

4. Title and Subtitle	5. Report Date
MASH TEST 3-11 OF THE TXDOT PORTABLE TYPE 2 PCTB WITH SIGN SUPPORT ASSEMBLY	October 2010 Published: January 2011
	6. Performing Organization Code
7. Author(s) William F. Williams and Wanda L. Menges	8. Performing Organization Report No. Report 0-6143-1
9. Performing Organization Name and Address Texas Transportation Institute Proving Ground The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project 0-6143
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Technical Report: September 2008 – August 2010 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Standards for Mounting Traffic Control Signs and Devices on Concrete Traffic Barrier (CTB) in Construction Work Zones

URL: http://tti.tamu.edu/documents/0-6143-1.pdf

16. Abstract

Portable concrete traffic barriers (PCTBs) are commonly used in work zones or in temporary median barrier applications. PCTBs are needed for separation and channelization of vehicle movement and for worker protection. Signage is often necessary wherever PCTBs are used. Placement of signs where driver visibility is optimal is often necessary. It might be desirable to place signs in the shoulder of the left hand lane between the PCTB and the roadway. Signs placed in the shoulder of roadways are often supported by skids that are weighted down with sand bags. Often, there is not enough shoulder width for these skid-type sign supports. One solution would be to mount the sign supports directly on the PCTB.

The goal of this project was to develop a sign support mount connection that could be incorporated into the Texas Department of Transportation (TxDOT) standard specifications for sign supports used in construction zones. This report presents the details of the design developed for mounting the traffic control sign support on top a PCTB, description of the full scale crash test performed on the design, and an assessment and evaluation of the performance of the PCTB with the sign support mounted on top according to specifications of *Manual for Assessing Safety Hardware* (*MASH*).

The PCTB mounted sign support assembly anchored to the top of the TxDOT Type 2 PCTB tested for this project performed acceptably for *MASH* test 3-11. Based on the successful crash performance, the sign support assembly anchored to the top of the TxDOT Type 2 PCTB, in conjunction with the steel strap connection plates, as tested for this project, is recommended for implementation.

17. Key Words	18. Distribution Statement
Sign Supports, Longitudinal Barriers, Portable Concrete Barriers, Concrete Traffic Barriers, CTB, Crash Testing, Roadway Safety	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	60	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

MASH TEST 3-11 OF THE TxDOT PORTABLE PCTB WITH SIGN SUPPORT ASSEMBLY

by

William F. Williams, P.E.
Assistant Research Engineer
Texas Transportation Institute

and

Wanda L. Menges
Research Specialist
Texas Transportation Institute

Report 0-6143-1
Project 0-6143
Project Title: Standards for Mounting Traffic Control Signs and Devices on Concrete Traffic Barrier (CTB) in Construction Work Zones

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

October 2010
Published: January 2011

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. The engineer in charge of the project was William F. Williams, P.E. (Texas, #71898).

TTI PROVING GROUND DISCLAIMER

The results of the crash testing reported herein apply only to the article being tested.

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Wanda L. Menges, Research Specialist
Deputy Quality Manager

Richard A. Zimmer, Senior Research Specialist
Test Facility Manager
Quality Manager
Technical Manager

ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the Federal Highway Administration. The TxDOT project director for this research was Tracey Friggle. Other members of the project team with TxDOT were Stuart Corder, Wade Odell, Mark Olson, Kelly Selman, and Doug Skowronek. The authors acknowledge and appreciate their guidance and assistance.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1. INTRODUCTION

INTRODUCTION

Portable concrete traffic barriers (PCTBs) are commonly used in work zones or in temporary median barrier applications. PCTBs are needed for separation and channelization of vehicle movement and for worker protection. Signage is often necessary wherever temporary PCTBs are used. Placement of signs where driver visibility is optimal is often necessary. It might be desirable to place signs in the shoulder of the left hand lane between the PCTB and the roadway. Signs placed in the shoulder of roadways are often supported by skids that are weighted down with sand bags. Often, there is not enough shoulder width for these skid-type sign supports. Skid sign support have a potential to be hit, thus creating debris, and reducing the effectiveness of these signs. One solution would be to mount the sign supports directly on the PCTB. The goal of this research is to develop a sign support mount connection that could be incorporated into the Texas Department of Transportation (TxDOT) standard specifications for signs used in construction work zones.

BACKGROUND*

Specific conditions in the work zone require that construction signs be placed on the left side of a roadway. This requires that signs be placed on skid supports and placed on the interior shoulder. This practice removes usable shoulder width from a driver's perspective. It also requires the use of large shoulders to provide the appropriate amount of clearance for travel lanes, reducing available space for construction zones. Signs used in this location are large and often require dual support skid systems. In addition, signs located in the shoulder of the roadway pose a greater risk for errant vehicles due to the close proximity to the roadway. These signs tend to reduce the limited right of way and reduce the visibility for motorists. Also, the skid support systems used to support these signs in the shoulder areas tend to collect debris and often restrict the hydraulics in the shoulder area. Signs located in the shoulder area are more frequently damaged due to the close proximity to large trucks. In construction work zones, clear shoulders are often needed for detours. Signs located in the shoulder areas reduce the available width for traffic using the shoulder area for travel.

In order to provide a solution or minimization for risk to the previously stated problems, it was suggested that a system be developed to place sign supports on median barriers. This would reduce the required width of shoulder by moving the sign farther from the roadway. By decreasing the width of required shoulder, the available construction zone area would increase. In return, this would increase efficiency of construction and reduce the risk of worker injury. In addition, by moving sign supports onto the top of median barriers, all sign obstacles from the shoulder area could be removed.

---

* *The opinions/interpretations expressed in this section are outside the scope of TTI Proving Ground's A2LA accreditation.*

The removal of skid supports from interior shoulders would result in less buildup of trash. Two problems arise from the buildup of trash in the sign supports. The first problem is the added cost of cleaning up the collected trash on a more frequent basis. Second is the dramatic increase in risk of water intruding into the roadway induced by collected trash and the skid supports obstructing drains and ducts. Removing the skid supports from the shoulder can reduce the risk due to water protruding into travel lanes.

Similar products have been developed to address these same issues on bridges by attaching signs off the back side of the barriers and out of the zone of intrusion. However, this solution is not feasible for temporary median barrier applications. To further complicate the design, work zone signs are typically supported by dual support skid systems. There is no practical way of attaching a dual support system to the center of a barrier in a median application in a construction work zone. This alludes to the fact that a new single support system must be designed that can handle wind, ice, and other environmental loads, as well as impact loads for the desired sign size.

Midwest Roadside Safety Facility (MwRSF) has run several tests where attachments have been mounted on the top of a barrier (*1-4*). As part of this research, a review of previous crash tests was conducted on crash tested bridge railings and median barriers with attachments such as signs and luminaires. Based on this review, zones of influence (ZOI) were established at test levels provided in the National Cooperative Highway Research Program (NCHRP) *Report 350* guidelines (*5*). Three test levels were studied: TL-2, TL-3, and TL-4. Next, a field investigation was conducted to determine the types of traffic barrier attachments currently in place. The attachments were classified according to the level of hazard they were believed to present. Finally, recommendations for placement and/or design of the attachments were made based on the combined results from the crash test review and field investigation. The goal of this research was to provide quantitative definition on how far behind and above a barrier a designer should place attachments and to make some general suggestions on how to design attachments to eliminate safety concerns. A large variety of attachments are currently in use on bridge rails and median barriers and very often the design of these attachments is handled on a case-by-case basis. Variations in bridge structure and deck design, roadway characteristics around the median barriers and bridges, and the type of traffic barrier itself, have implications to the attachment design. Using the intrusion around a barrier as the basis for the design provides an approach to generalize design attachments based on a limited number of full-scale crash evaluations.

The recommendations from the MwRSF studies resulted in general guidelines for the placement of attachments within a given ZOI. The information provided in the report was based on the best available engineering judgement and limited full-scale crash data. There were only a few crash tests of actual barrier attachments on which to base this judgment. It was concluded that further research and testing was needed to determine final design criteria for the placement of attachments on barrier systems.

In summary, the intrusion zones for TL-3 concrete barriers and steel tubular rails on curbs consisted of an area above the barriers that is 18 inches wide and extends above the barrier to a height of 78 inches above the pavement surface. For TL-4 railing systems, the intrusion zones consisted of an area above the barriers that is 24 inches in width and extends above the barriers to a height of 78 inches above the pavement surface.

OBJECTIVES/SCOPE OF RESEARCH

PCTBs used by TxDOT were reviewed to determine a worst case impact scenario for the full-scale crash test and to determine if the final designs could be uniformly attached to all barrier types without modification. The selected design was tested according to the American Association of State Highways and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*6*).

The placement of signs in construction work zones are sometimes needed on the left side of a divided roadway. Signs placed on the left side of the roadway are typically supported by a skid mounted system. Skid mounted systems require shoulder space. Shoulder space in the construction work zones may be very limited or not existent. Mounting the sign on top of a portable concrete median barrier used in the work zone is one option for supporting the sign. The purpose of this project was to develop a crashworthy sign support that can be attached to the top of the TxDOT PCTB. The goal of this research was to develop and successfully crash test a concrete traffic barrier (CTB)-mounted sign support assembly that could be incorporated into the TxDOT standard specifications for signs used in construction zones. This report presents the details of the design developed for the sign support connection mounted on top of a PCTB, description of the full scale crash test performed on the sign support assembly, and an assessment and evaluation of the performance of this assembly anchored to the top of the TxDOT Type 2 PCTB according to specifications set forth in *MASH*.

CHAPTER 2. CRASH TEST PROCEDURES

TEST FACILITY

The full-scale crash test reported herein was performed at the Texas Transportation Institute (TTI) Proving Ground. The TTI Proving Ground is an International Standards Organization (ISO) 17025 accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures and according to the *MASH* guidelines and standards.

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for placement and testing of the TxDOT Type 2 PCTB with sign support assembly anchored to the top of the barrier system evaluated under this project is on the surface of an existing out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5 ft by 15 ft blocks nominally 8 to 12 inches deep. The apron is over 50 years old, and the joints have some displacement, but are otherwise flat and level.

TEST ARTICLE

The test article consisted of a 48-inch x 48-inch x 5/8-inch thick plywood sign panel, sign support post, and sign support connection anchored to the top of a TxDOT Type 2 PCTB(2) portable concrete traffic barrier. The height to the bottom of the sign panel in the test installation was 7 ft. The sign support connection was anchored to the top of the CTB centered over a joint of two adjoining 30-ft sections of CTB. The sign support connection consisted of an HSS6x2x1/4 A500 Grade B structural steel tube with a 3-inch diameter schedule 40 steel collar welded to the steel tube. The total height of the sign support connection with steel collar was 6-1/2 inches. The sign post consisted of a 2-1/2-inch diameter Schedule 80 pipe that fit inside the 3-inch diameter steel collar. This steel collar was welded to the steel tube connection. A 1/2-inch diameter Grade 5 hex head bolt was used to connect the sign post to the sign support connection. The length of the HSS6x2x1/4 steel tube was 72 inches. The sign support connection was anchored to the top of the CTB using four 3/4-inch diameter galvanized Hilti HAS-E rods (two anchor rods in each adjoining barrier section), 10 inches in length and embedded a minimum of 8 inches in the top of the CTB barrier. The HAS-E rods were anchored to the barrier using a Hilti HY 150 Adhesive Anchoring System. These anchor rods were located along the centerline of the steel tube connection and widely spaced along the length of the steel tube.

Eight 30-ft long TxDOT Type 2 barrier sections were joined together using the TxDOT grid slot connection, as shown in Figures 1 through 4. This connection consists of six pieces of #8 rebar welded to two pieces of #4 rebar. This connection is commonly used to connect the TxDOT Type 2 portable concrete traffic barrier system. The total length of the installation was approximately 240 ft. In addition to the grid slot connections in the barrier, three barrier joints in the installation were reinforced with anchored steel strap connection plates located approximately 8-1/4 inches above the base of the barrier and on each side of the barrier (two connection plates each joint). These anchored steel strap connection plates were used to increase the stiffness of the joined connections in the immediate area of the sign support. They were installed at the barrier connection joint at the location of the sign support and at two barrier joints adjacent to the sign support. The TxDOT Type 2 PCTB with grid slot connection and anchored steel strap connection plates was successfully crash tested to *NCHRP Report 350* TL-3 specification in August 2001 (TTI Project No. 441621-3). However, one strap was ruptured in this crash test and the recommended strap thickness from this research was 1/4-inch. These two steel strap connection plates for this project consisted of a 4-inch wide by 1/4-inch thick A36 steel plate, 48 inches in length anchored to the base of the CTB using four Hilti 20 mm diameter HSL-3 M20/30 Expansion Anchors (two each barrier end). For additional information please refer to Figures 1 through 4. Photographs of the completed installation are shown in Figure 5.

CRASH TEST CONDITIONS

According to *MASH*, three tests are recommended to evaluate work zone traffic control devices, such as the CTB mounted sign support for construction zones, to test level 3 (TL-3):

> ***MASH* test 3-70**: An 1100C (2425 lb/1100 kg) vehicle impacting the device at a nominal impact speed of 30 mi/h and critical impact angle (CIA) judged to have the greatest potential for test failure. This test is to investigate a device's ability to successfully activate by breakaway, fracture, or yielding mechanism during low-speed impact by a small vehicle.
>
> ***MASH* test 3-71**: An 1100C (2425 lb/1100 kg) vehicle impacting the device at a nominal impact speed of 62 mi/h and CIA judged to have the greatest potential for test failure. This is intended to evaluate the behavior of the device during high-speed impacts with a small vehicle.
>
> ***MASH* test 3-72**: A 2270P (5000 lb/2270 kg) vehicle impacting the device at a nominal impact speed of 62 mi/h and CIA judged to have the greatest potential for test failure. This is intended to evaluate the behavior of the device during high-speed impacts with a pickup truck.
>
> Two tests are recommended to evaluate longitudinal barriers, such as the CTB, to TL-3:
>
> ***MASH* test 3-10**: An 1100C (2425 lb/1100 kg) vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test is to investigate a barrier's ability to successfully contain and redirect a small passenger vehicle.

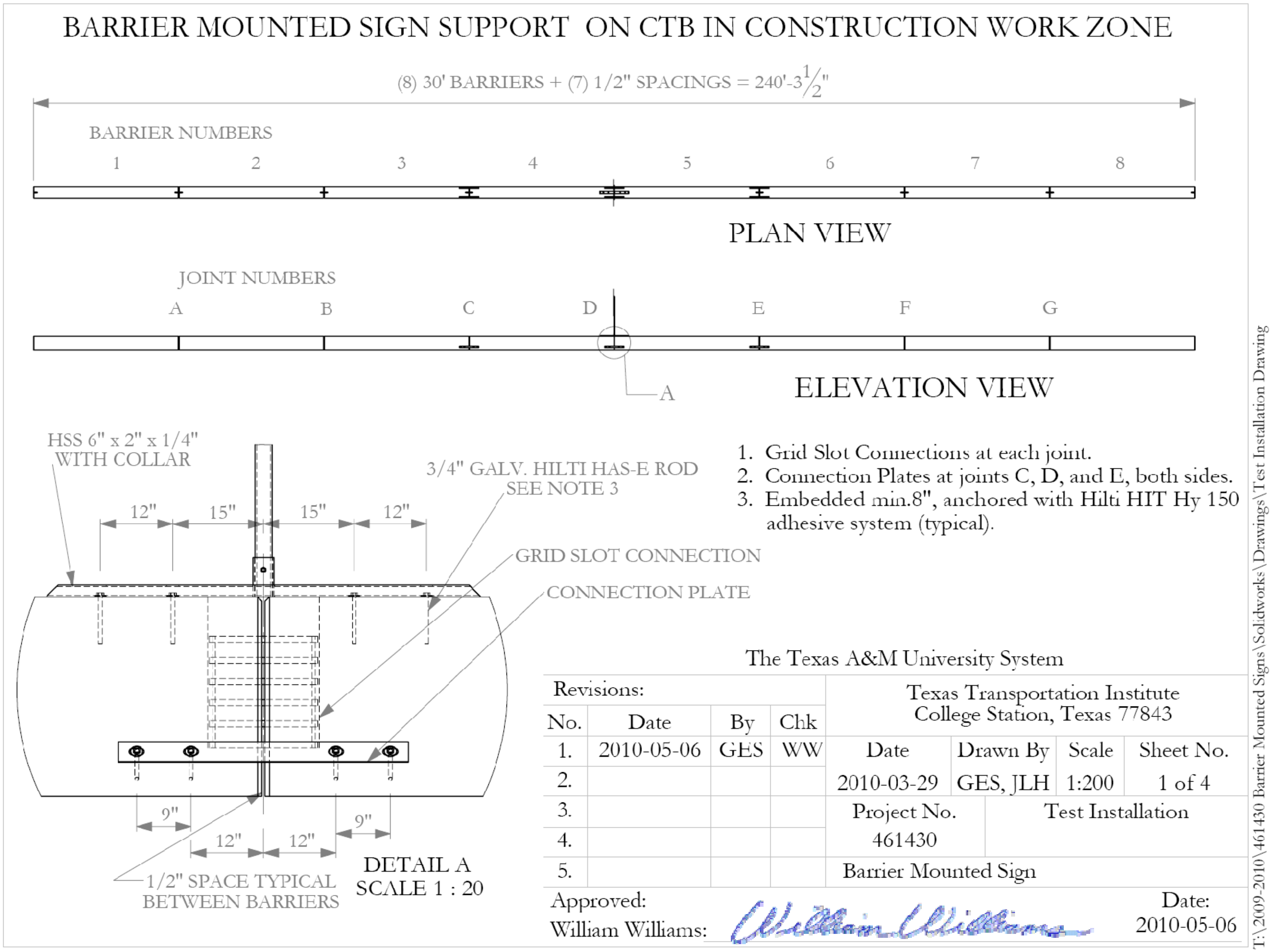


Figure 1. Details of the TxDOT PCTB Sign Support Assembly.

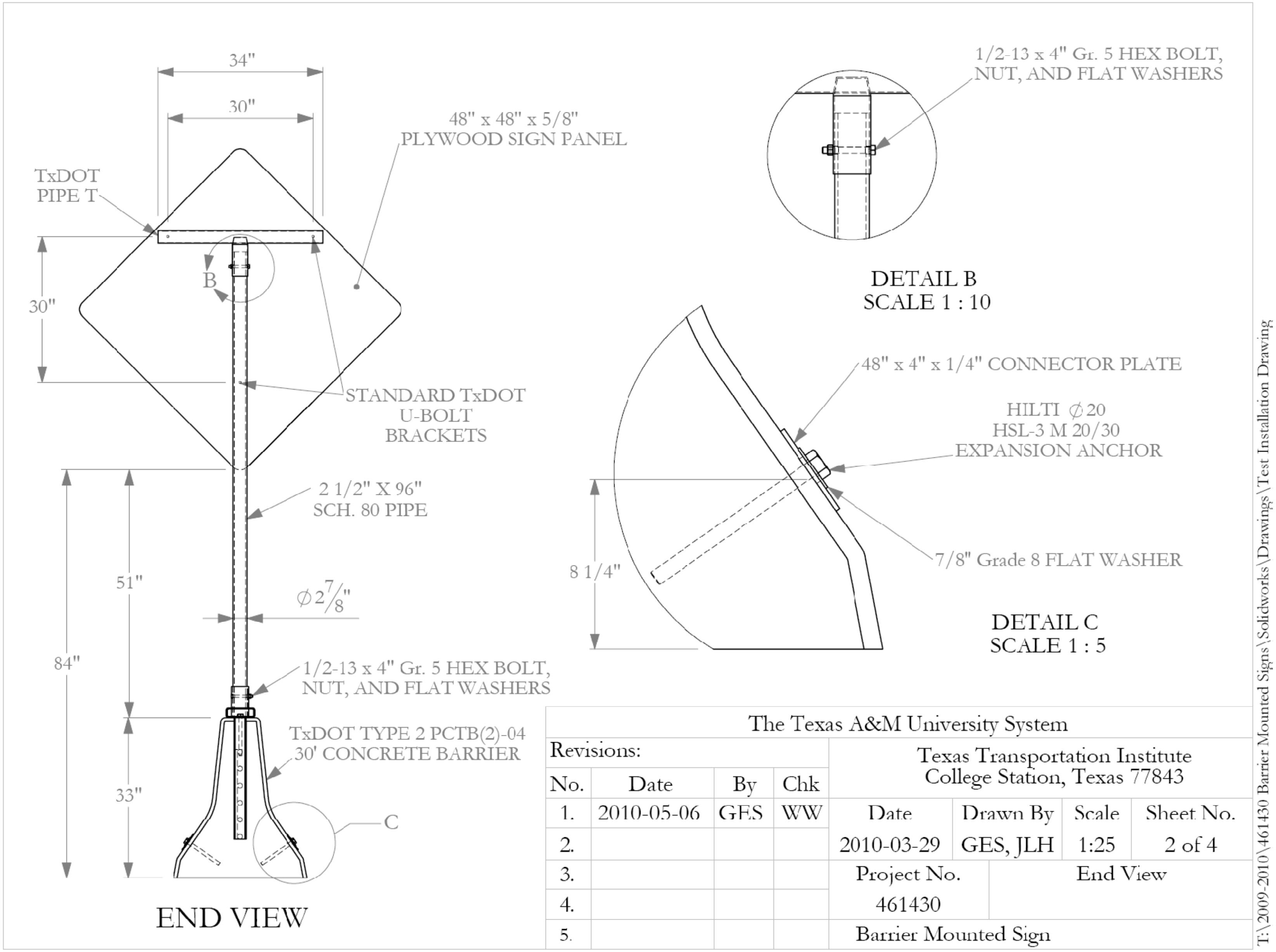


Figure 2. Details of the TxDOT Type 2 PCTB Sign Support Assembly.

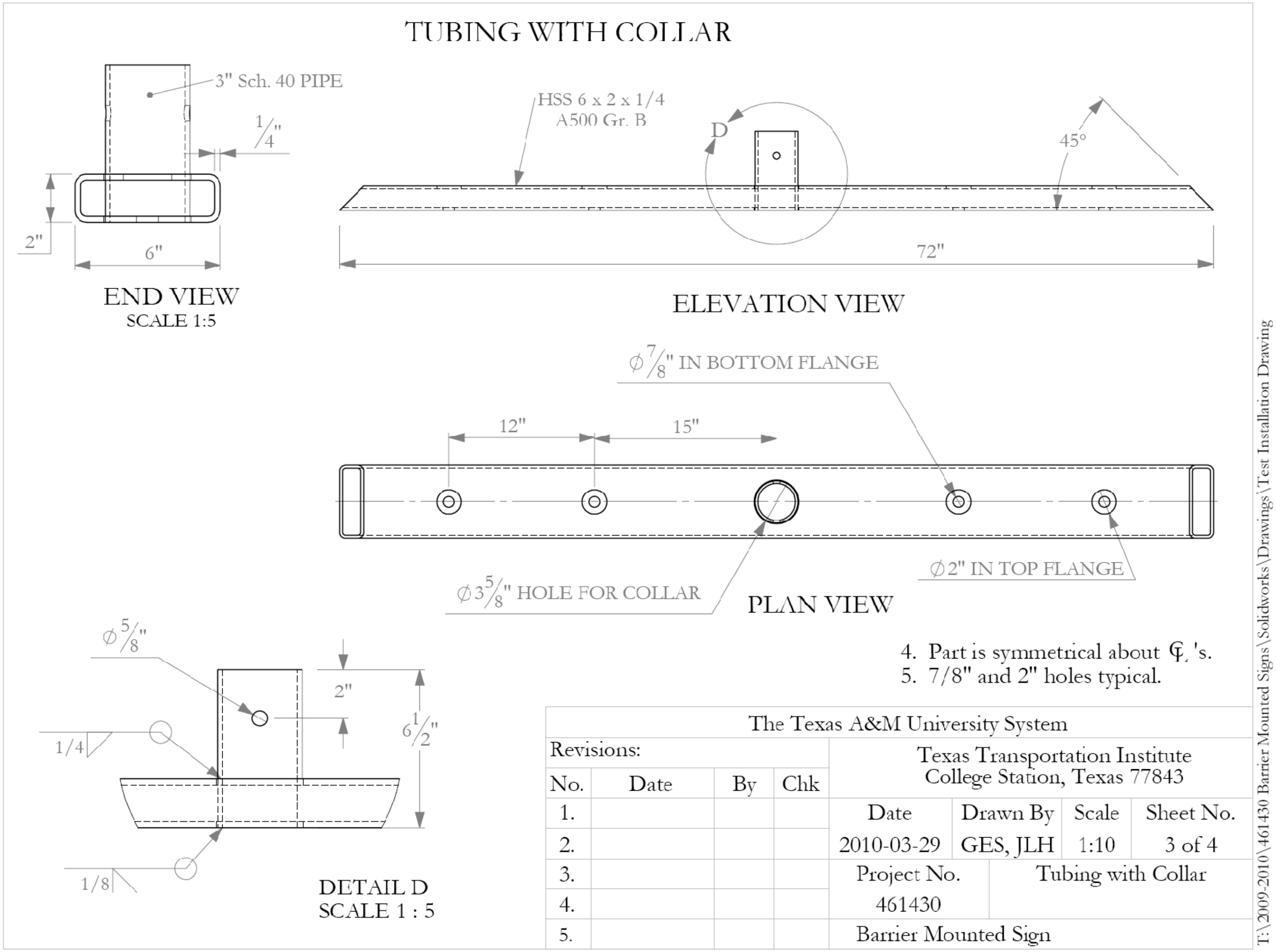


Figure 3. Details of the TxDOT Type 2 PCTB Sign Support Connection.

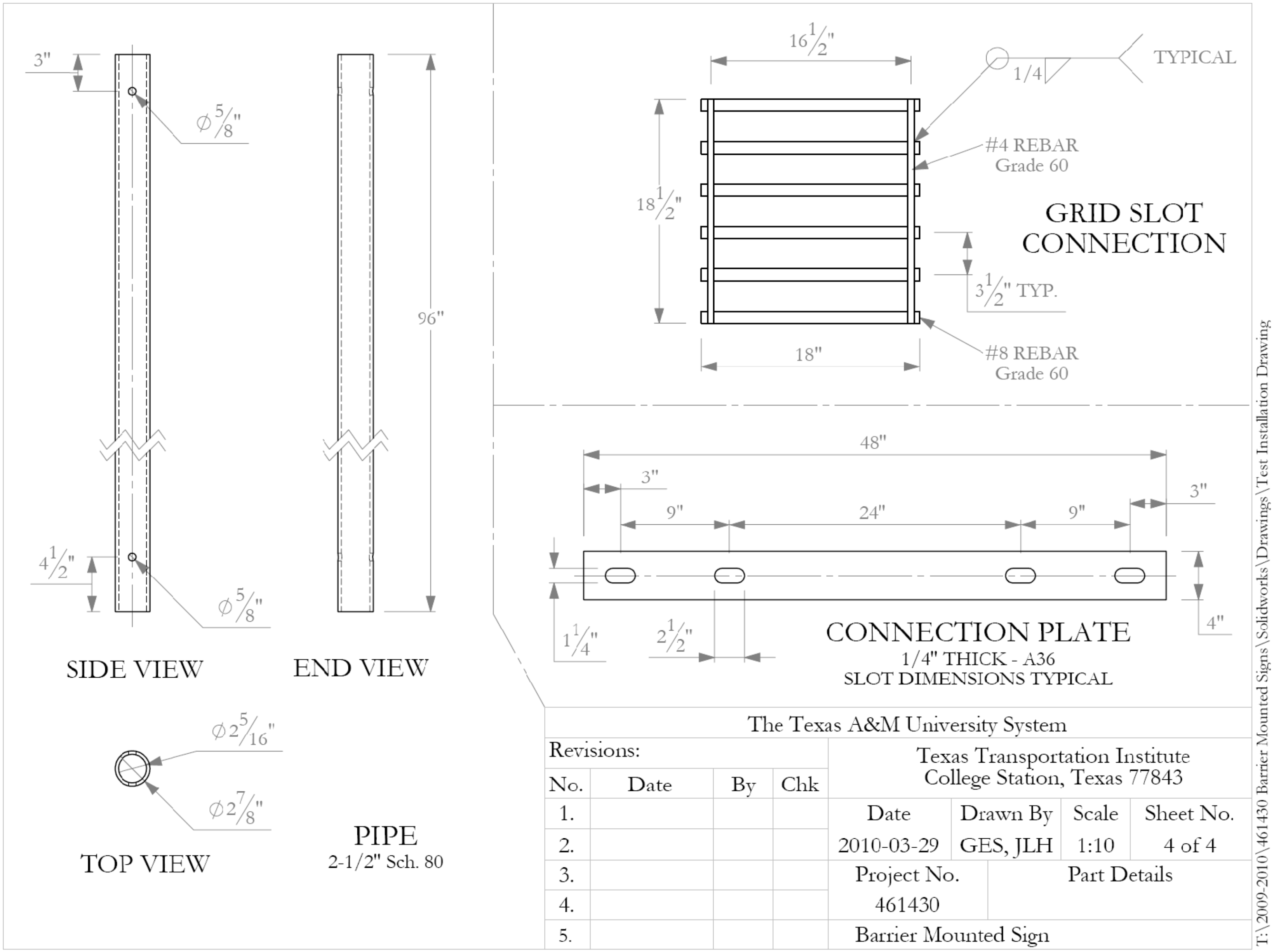


Figure 4. Details of the Grid Slot and Connection Plate.

Figure 5. TxDOT PCTB with Sign Support Assembly and Steel Strap Connections before Test No. 461430-1.

***MASH* test 3-11**: A 2270P (5000 lb/2270 kg) vehicle impacting the CIP of the LON of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This is a strength test for test levels 1 through 3 to verify a barrier's performance for impacts involving light trucks and SUVs for all test levels.

Test 3-11 was the appropriate test since interaction of the pickup with the sign attached to the barrier was more likely. The test reported herein corresponds to *MASH* tests 3-11. Target impact point for this test was 9 ft upstream of centerline of joint between TxDOT CTB sections 4 and 5, with the work zone traffic sign support mounted at the joint between sections 4 and 5. This CIP was selected based on the crash performance of the pickup truck in the crash test performed on the TxDOT Type 2 PCTB with steel strap connection plates in August 2001 (TTI Project No. 441621-3). Based on the review of the video from this test, at approximately 9 ft from the CIP, the maximum intrusion of the truck over the barrier occurred. This same CIP was selected for this test to maximize the vehicle interaction with the sign and sign connection.

All crash test, data analysis, and evaluation and reporting procedures followed under this project were in accordance with guidelines presented in *MASH*. Appendix A presents brief descriptions of these procedures.

EVALUATION CRITERIA

The crash test was evaluated in accordance with the criteria presented in *MASH*. The performance of the TxDOT Type 2 PCTB with sign support assembly anchored to the top of the barrier system is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged upon the ability of the TxDOT Type 2 PCTB with sign support assembly mounted atop the barrier to contain and redirect the vehicle or bring the vehicle to a controlled stop in a predictable manner. Occupant risk criteria evaluates the potential risk of hazard to occupants in the impacting vehicle and to some extent other traffic, pedestrians, or workers in construction zones, if applicable. Post impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from table 5.1 of *MASH* were used to evaluate the crash test reported herein and are listed in further detail under the assessment of the crash test.

CHAPTER 3. CRASH TEST RESULTS

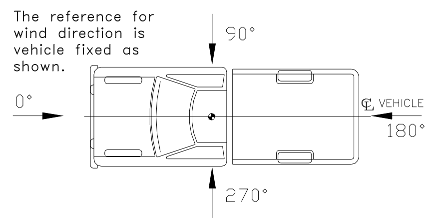
TEST NO. 461430-1 (*MASH* TEST 3-11)

Test Vehicle

A 2005 Dodge Ram 1500 pickup truck, shown in Figures 6 and 7, was used for the crash test. Test inertia weight of the vehicle was 5000 lb, and its gross static weight was 5000 lb. The height to the lower edge of the vehicle bumper was 13.5 inches, and it was 16.0 inches to the upper edge of the bumper. Height to the vehicle center of gravity was 28.5 inches. Figure 13 and Table 2 in Appendix B give additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system and was released to be free-wheeling and unrestrained just prior to impact.

Weather Conditions

The test was performed on the afternoon of May 24, 2010. Rainfall of 1.4 inches was recorded seven through 10 days prior to the test date. Weather conditions at the time of testing were as follows: Wind speed: 7 mi/h; Wind direction: 121 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 87°F; Relative humidity: 56 percent.



Test Description

The 2005 Dodge Ram 1500 pickup truck, traveling at an impact speed of 63.5 mi/h, impacted the TxDOT CTB 10.0 ft upstream of the joint between sections 4 and 5 at an impact angle of 24.6 degrees. At approximately 0.016 s, the vehicle began to redirect, and at 0.020 s, the top of PCTB section 4 began to deflect toward the field side. A crack on the field side of PCTB section 4 began to form at 0.038 s, and PCTB section 5 began to deflect toward the field side at 0.040 s. At 0.082 s, the vehicle contacted the base of the PCTB mounted sign support and PCTB section 5. As the vehicle continued forward, the left front exterior fender panel of the vehicle caught on the sign support and the fender pulled away from the vehicle. The vehicle then began to ride along the top of the PCTB. At 0.210 s, the vehicle lost contact with the barrier and was traveling at an exit speed of 54.6 mi/h and 6.9 degrees. At 0.310 s, the bed of the truck lost contact with the sign support. Brakes on the vehicle were applied at 2.4 seconds after impact, and the vehicle subsequently came to rest facing the PCTBs 223 ft downstream of impact and 33 ft toward the field side of the PCTBs. Figures 14 and 15 in Appendix C show sequential photographs of the test period.

Figure 6. Vehicle and Installation Geometrics for Test No. 461430-1.

Figure 7. Vehicle before Test No. 461430-1.

Damage to Test Installation

Figures 8 and 9 show damage to the PCTB mounted sign assembly after the test. PCTB section 4 ruptured through the concrete and all but the lower two longitudinal rebar 78 inches upstream of the joint between sections 4 and 5. Length of contact of the vehicle with the barrier was 43.2 ft. Working width with the vehicle and the PCTB only was 5.8 ft. Working width with the vehicle and the PCTB mounted sign support was 10.2 ft (due to lean of the top of the sign support). Maximum dynamic deflection of the barrier during the test was 3.9 ft, and maximum dynamic deflection of the PCTB mounted sign support was 4.3 ft.

Vehicle Damage

Damage to the 2270P vehicle is shown in Figure 10. The left upper and lower ball joints of the front suspension were broken and the tie rod was deformed. Also damaged were the front bumper hood, grill, left front fender, left front and rear doors, left exterior bed, and rear bumper. The left front wheel rim was deformed and the tire deflated. The left rear wheel rim was also deformed, however, the tire remained inflated. Maximum exterior crush to the vehicle was 13.0 inches in the frontal plane at the left front corner at bumper height. Maximum occupant compartment deformation was 4.0 inches in the left firewall area near the toe pan. Photographs of the interior of the vehicle are shown in Figure 11. Exterior vehicle crush and occupant compartment measurements are shown in Appendix B, Tables 3 and 4.

Occupant Risk Factors

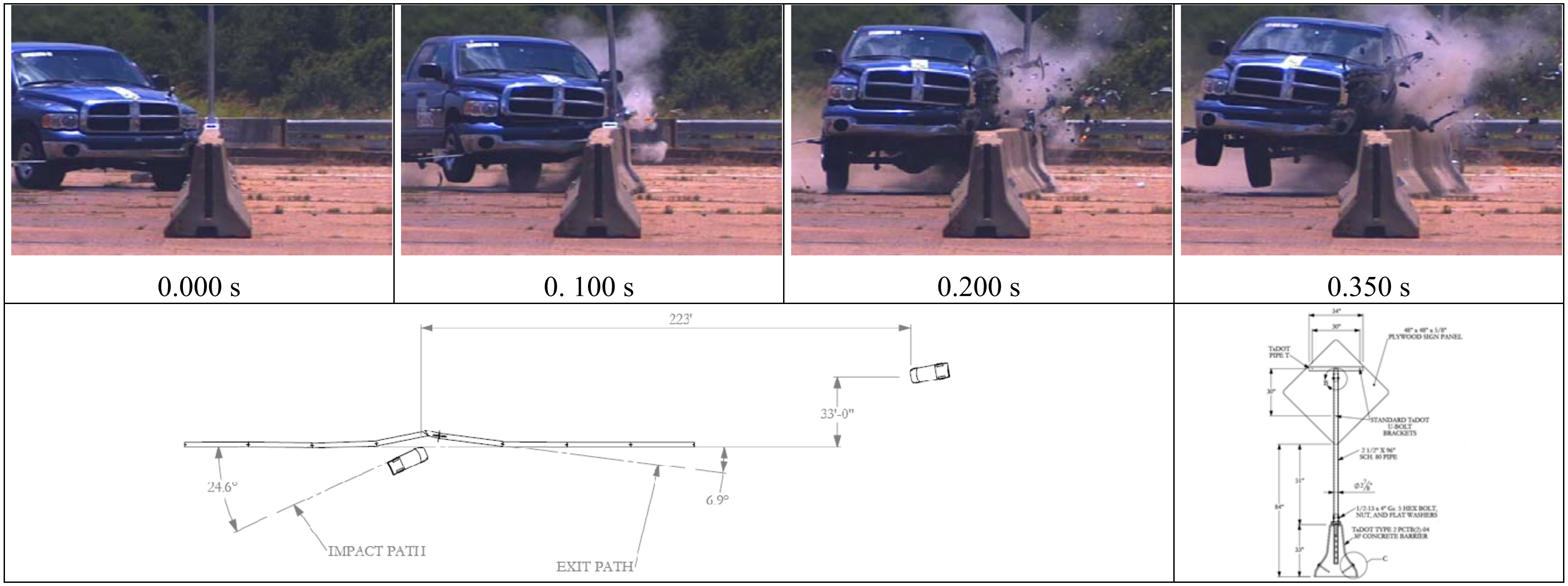
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 13.8 ft/s at 0.101 s, the highest 0.010-s occupant ridedown acceleration was −10.3 Gs from 0.117 to 0.127 s, and the maximum 0.050-s average acceleration was −5.5 Gs between 0.019 and 0.069 s. In the lateral direction, the occupant impact velocity was 21.3 ft/s at 0.101 s, the highest 0.010-s occupant ridedown acceleration was 9.8 Gs from 0.232 to 0.242 s, and the maximum 0.050-s average was 11.1 Gs between 0.034 and 0.084 s. Theoretical Head Impact Velocity (THIV) was 27.8 km/h or 7.7 m/s at 0.098s; Post-Impact Head Decelerations (PHD) was 10.3 Gs between 0.118 and 0.128 s; and Acceleration Severity Index (ASI) was 1.27 between 0.034 and 0.084 s. These data and other pertinent information from the test are summarized in Figure 12. Vehicle angular displacements and accelerations versus time traces are presented in Appendix D Figures 16 through 22.

Figure 8. After Impact Vehicle Position for Test No. 461430-1.

Figure 9. Installation after Test No. 461430-1.

Figure 10. Vehicle after Test No. 461430-1.

Figure 11. Interior of Vehicle for Test No. 461430-1.



General Information	
Test Agency	Texas Transportation Institute
Test Agency Test No.	461430-1
Test Standard Test No.	*MASH* 3-11
Date	2010-05-24
Test Article	
Type	Concrete Traffic Barrier (CTB)
Name	CTB Mounted Sign Support
Installation Length	240 ft 3-1/2 inches
Material or Key Elements	30 ft Concrete Safety Shape Barrier with Schedule 80 Sign Support
Soil Type and Condition	On Concrete Pavement, Dry
Test Vehicle	
Type/Designation	2270P
Make and Model	2005 Dodge Ram 1500 Pickup
Curb	4791 lb
Test Inertial	5000 lb
Dummy	No dummy
Gross Static	5000 lb

Impact Conditions	
Speed	63.5 mi/h
Angle	24.6 degrees
Location/Orientation	10 ft upstream of joint 4-5
Exit Conditions	
Speed	50.2 mi/h
Angle	
Occupant Risk Values	
Impact Velocity	
Longitudinal	13.8 ft/s
Lateral	21.3 ft/s
Ridedown Accelerations	
Longitudinal	−10.3 G
Lateral	9.8 G
THIV	27.8 km/h
PHD	10.3 G
ASI	1.27
Max. 0.050-s Average	
Longitudinal	−5.5 G
Lateral	11.1 G
Vertical	−2.7 G

Post-Impact Trajectory	
Stopping Distance	223 ft dwnstrm 33 ft twd field side
Vehicle Stability	
Maximum Yaw Angle	−32 degrees
Maximum Pitch Angle	−14 degrees
Maximum Roll Angle	−14 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	4.3 ft
Permanent	3.9 ft
Working Width	10.2 ft
Vehicle Damage	
VDS	11LD4
CDC	11FLEW3
Max. Exterior Deformation	13.0 inches
OCDI	LF0010000
Max. Occupant Compartment Deformation	4.0 inches

Figure 12. Summary of Results for *MASH* Test 3-11 on the TxDOT CTB Mounted Sign Support.

CHAPTER 4. SUMMARY AND CONCLUSIONS

ASSESSMENT OF TEST RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria for *MASH* test 3-11 on the TXDOT Type 2 PCTB with sign support assembly anchored to the top of the barrier is provided below.

Structural Adequacy

A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*

Result: The TxDOT Type 2 PCTB with sign support assembly anchored to the top of the barrier contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the PCTB. Maximum dynamic deflection during the test was 3.9 ft. (PASS)

Occupant Risk

D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches)

Result: PCTB section 4 fractured but remained partially connected with the installation. No penetration or potential for penetration occurred, and this did not present undue hazard for others in the area. (PASS)
Maximum occupant compartment deformation was 4.0 inches in the driver side firewall area near the toe pan. (PASS)

F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*

Result: The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch were both −14 degrees. (PASS)

H. Occupant impact velocities should satisfy the following:
Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
9.0 m/s (30 ft/s)	*12.2 m/s (40 ft/s)*

Results: Longitudinal occupant impact velocity was 13.8 ft/s, and lateral occupant impact velocity was 21.3 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Result: Maximum longitudinal occupant ridedown acceleration was −10.3 G, and maximum lateral occupant ridedown acceleration was 9.8 G. (PASS)

Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box.

Result: The 2270P exited within the exit box. (PASS)

CONCLUSIONS*

The purpose of this project was to develop a TxDOT standard for mounting traffic control signs and devices on concrete traffic barrier in construction work zones. For this project the TxDOT Type 2 Portable Concrete Traffic Barrier (PCTB) (2)-04 was selected as the concrete barrier used to support the new sign support connection developed for this project. This barrier type utilizes a steel grid slot connection fabricated using #8 grade 60 reinforcing steel. This barrier type and connection is most common in the current TxDOT inventory. The TxDOT Type 2 PCTB consists of 30 ft barrier segments.

In April 2002, the TxDOT Type 2 PCTB with grid slot connection was evaluated with respect to *NCHRP Report 350* guidelines (*7*). Under this project, TTI researchers and TxDOT engineers worked together to evaluate the crash performance of this barrier system and determine if cost effective modifications could be made to the barrier to meet *NCHRP Report 350* criteria and limit dynamic deflections to practical levels. The initial assessment of the barrier connection was that it would not perform satisfactorily with respect to *NCHRP Report 350* performance criteria. The initial assessment of the PCTB with grid slot connection was that it would separate and/or permit large deflections without additional reinforcement at the joint connection.

---

* *Except for the statement of this test's compliance with MASH, all other opinions/interpretations expressed in this section are outside the scope of TTI Proving Ground's A2LA accreditation.*

The research team performed various analyses to help assess the ability of the selected barrier system to meet *NCHRP Report 350* impact performance criteria prior to conducting the full scale crash testing. Computer simulation techniques were used to support the analysis effort. The simulation provided a more detailed understanding of the three-dimensional impact response of the barrier design. The program utilized in the computer modeling efforts was LS-DYNA. LS-DYNA is a general-purpose, explicit finite element code used to analyze the nonlinear dynamic response of three-dimensional inelastic structures. This code is capable of capturing many of the complex interactions that occur when a vehicle impacts a roadside safety structure. Limitations in the ability of existing material models to accurately capture concrete fracture and failure led to some simplifying assumptions regarding the model of the grid-slot connection. Nonetheless, the simulations assisted in the impact performance evaluation of the existing and modified designs.

For the TxDOT 0-4162 project, several retrofit connection designs were conceptualized for the objective of reducing dynamic barrier deflections. TxDOT engineers and TTI researchers developed the design modifications jointly. When developing these retrofit design options, factors such as impact performance, cost, ease of field installation, and aesthetics were considered. For this project, three full-scale crash tests were performed to evaluate the safety performance of the selected barrier system. The purpose of the testing was to assess compliance of the grid-slot PCTB with *NCHRP Report 350* and examine alternatives for reducing dynamic deflection. The tests were performed in the order of cost effectiveness of the barrier modifications to investigate the relative improvement in crash performance. All three crash tests satisfied *NCHRP Report 350* evaluation criteria.

One of the retrofit designs tested for this project (TxDOT Project 0-4162) consisted of two steel straps bolted to the base of the TxDOT PCTB. The new retrofit connection consisted of bolting a 4-inch wide by 3/16-inch thick steel strap across the barrier joint on both the front and back sides of the barrier. Two 1-1/4 inch by 2-1/2 inch slotted holes were fabricated into each end of the 48-inch long straps. The straps were anchored to the sloped face of the toe of each barrier using two M20/30 Hilti HSL heavy duty sleeve anchors embedded approximately 7 inches. A 7/8-inch Grade 8 flat washer was used beneath the head of each anchor bolt to span the slotted hole. The anchors were vertically located approximately 8-1/4 inches from the base of the barrier and were spaced 9 inches apart. Engineering analyses and computer simulations indicated that the steel straps should significantly increase the capacity of the barrier joint and improve/reduce the dynamic deflection of the barrier system. The steel straps were used in combination with the steel grid connection used between the barrier segments.

The crash test on the TxDOT Type 2 PCTB with grid-slot connections and steel straps was performed on August 24, 2001, for Project 0-4612 *(8)*. The results from the crash test were satisfactory with respect to *NCHRP Report 350* criteria. The vehicle traveling at a speed of 62.5 mi/h, impacted the PCTB 3.75 ft upstream of a joint near the middle part of the installation, which was approximately 240 ft-3-1/2 inches in length. One of the 3/16-inch steel straps in the immediate impact area ruptured from the impact force. The test met all the applicable *NCHRP Report 350* safety evaluation criteria. In summary, the modified Texas grid-slot PCTB with the plate connector straps and rebar grid met *NCHRP Report 350* evaluation criteria. The plate connector substantially reduced the maximum dynamic deflection of the barrier. The maximum lateral barrier movement experienced in the test was approximately 4.0 ft. The maximum roll angle at the point of impact at the barrier joint was approximately 5 degrees. The intrusion of the vehicle over the barrier was estimated to be approximately 6 inches.

The modified Texas grid-slot PCTB with the plate connector straps and rebar grid tested under TxDOT Project 0-6162 was utilized for the barrier tested for this project. Since the connector strap was ruptured in the crash test performed under TxDOT project 0-4162, the thickness of this strap was increased to ¼-inch thickness to improve the performance barrier when used in conjunction with the sign support connection. The sign support connection designed for this project served to provide support for the sign post and sign, as well as provide additional stiffness of the joint in the immediate impact area of the barrier. Minimizing the roll angle of the vehicle and minimizing intrusion of the vehicle over the barrier immediately after impact was deemed necessary for the successful performance of the sign support connection tested on top of the TxDOT Type 2 PCTB. The sign support connection developed for this project was designed to improve the stiffness of the barrier joint by the added bending strength of the connection tube and the four adhesive anchors used in the connection (two each side of the joint). Therefore, TTI researchers recommend using the sign support connection developed for this project at a joint in the TxDOT PCTB barrier system in conjunction with the ¼-inch thick plate connector straps at the joint and at adjacent joints (two) in the installation.

TTI researchers considered the information from the ZOI study performed by MwRSF. The recommendations from the MwRSF study resulted in general guidelines for the placement of attachments within a given ZOI. At the time of this study, the information provided in the report was based on the best available engineering judgment and limited full-scale crash data. At the time of the report, there were only a few crash tests of actual barrier attachments on which to base this judgment. The ZOI information developed from this study was suggested and further research was recommended to produce final criteria for the placement of attachments on barrier systems. In summary, the intrusion zones for TL-3 concrete barriers (with a sloped face 30 inches to 32 inches in height) consisted of an area above the barriers that is 18 inches wide and extents above the barrier to a height of 78 inches above the pavement surface. For TL-4 railing systems with barrier heights in the range of 28 inches to 42 inches, the intrusion zones for the truck cab consisted of an area above the barriers that is 34 inches in width and extends above the barriers to a height of 96 inches above the pavement surface. The height and width of the ZOI is 120 inches and 80 inches, respectively for the box van cargo box. Based on this study, it was recommended that the impact performance of an attachment and its placement that does not follow these suggested criteria can only be verified through the use of full-scale crash testing. Based on the information from this study, reducing the roll of the vehicle and the likely interaction of the vehicle with the sign was important to the success of the sign mount connection and sign support developed for this project. Removing the sign and sign connection out of the recommended ZOI for TL-3 from the MwRSF (18 inches) was not possible considering the attachment of the sign to the top of the portable concrete barrier used in a median application with traffic on both sides of the barrier. Therefore, reducing the intrusion of the vehicle (ZOI) over the barrier immediately after impact and reducing the roll of the vehicle over the barrier was important to the success of the sign mount and connection developed for this project.

The sign support and sign mount connection anchored to the top of the TxDOT Type 2 CTB and tested for this project performed acceptably for *MASH* test 3-11, as shown in Table 1. The steel straps added to the barrier connection at the sign mount connection as well as at the joint upstream and downstream of the sign mount connection improved the performance of the vehicle by minimizing the intrusion of the vehicle over the barrier (reducing snagging of the vehicle on the sign support and sign mount connection). In addition, the steel straps and sign mount connection helped in minimizing the roll of the vehicle over the barrier (also, reducing the snagging of the vehicle from rolling into the sign post, sign, and sign support connection).

Table 1. Performance Evaluation Summary for *MASH* Test 3-11 on the TxDOT PCTB with Sign Support Mounted on Top.

Test Agency: Texas Transportation Institute | Test No.: 461430-1 | Test Date: 2010-05-24

***MASH* Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The TxDOT CTB with sign support mounted on top contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the CTB. Maximum dynamic deflection during the test was 3.9 ft.	Pass
Occupant Risk D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	CTB section 4 fractured but remained partially connected with the installation. No penetration or potential for penetration occurred, and this did not present undue hazard for others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 4.0 inches in the driver side firewall area near the toe pan.	Pass
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch were both −14 degrees.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 9.1 m/s (30 ft/s), or at least below the maximum allowable value of 12.2 m/s (40 ft/s).*	Longitudinal occupant impact velocity was 13.8 ft/s, and lateral occupant impact velocity was 21.3 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.*	Maximum longitudinal occupant ridedown acceleration was −10.3 G, and maximum lateral occupant ridedown acceleration was 9.8 G.	Pass
Vehicle Trajectory *For redirective devices, the vehicle shall exit the barrier within the exit box.*	The 2270P vehicle exited within the exit box.	Pass

CHAPTER 5. IMPLEMENTATION STATEMENT

The sign support assembly anchored to the top of the TxDOT Type 2 tested for this project performed acceptably for *MASH* test 3-11. TTI researchers recommend the implementation of the sign support assembly anchored to the TxDOT Type 2 PCTB in conjunction with the steel strap connections to the three barrier joints as tested for this project and described herein. This recommendation is based on the successful crash performance of this design with respect to *MASH* criteria.

REFERENCES

[1] J. A. Hascall, K. A. Polivka, J. R. Rohde, R. K. Faller, D. L. Sicking, and J. C. Holloway, "Design and Evaluation of an Open Traffic/Bicycle Bridge Railing System," Report No. TRP-03-162-07. Midwest Roadside Saftey Facility, Lincoln, NE, February 2007.

[2] E. A. Keller, D. L. Sicking, R. K. Faller, K. A. Polivka, and J. R. Rohde, "Guidelines for Attachments to Bridge Rails and Median Barriers," Report No. SPR-3(017). Midwest Roadside Safety Facility, Lincoln, NE, February 2003.

[3] K. A. Polivka, R. K. Faller, E. A. Keller, D. L. Sicking, J. R. Rohde, and J. C. Holloway, "Design and Evaluation of the TL-4 Minnesota Combination Traffic/Bicycle Bridge Rail," Report No. SPR-3(017). Midwest Roadside Safety Facility, Lincoln, NE, November 1998.

[4] M. J. Wiebelhaus, K. A. Polivka, R. K. Faller, J. R. Rohde, D. L. Sicking, J. C. Holloway, J. D. Reid, and B. W. Bielenberg, "Evaluation of Rigid Hazards Placed in the Zone of Intrusion," Report No. TRP-03-151-08. Midwest Roadside Safety Facility, Lincoln, NE, January 2008.

[5] H. E. Ross, D. L. Sicking, R. A. Zimmer, and J. D. Michie, "Recommended Procedures for the Safety Performance Evaluation," in *NCHRP Report 350*, ed. National Academy Press, Washington, D.C.: National Cooperative Highway Research Program, 1993.

[6] AASHTO, "Manual for Assessing Safety Hardware," ed. Washington, DC: American Association of State Highway and Transportation Officials, 2009.

[7] R. P. Bligh, D. L. Bullard, W. L. Menges, and B. G. Butler, "Evaluation of Texas Grid-Slot Portable Concrete Barrier System," Report 0-4162-1. Texas Transportation Institute, Texas A&M University, College Station, TX, April 2002.

[8] R. P. Bligh, N. M. Sheikh, W. L. Menges, and R. R. Haug, "Development of Low-Deflection Precast Concrete Barrier," Report No. 0-4162-3. Texas Transportation Institute, Texas A&M University, College Station, TX, January 2005.

APPENDIX A. CRASH TEST AND DATA ANALYSIS PROCEDURES

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Brief descriptions of these procedures are presented as follows.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, that measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra small size, solid state units designs for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once recorded, the data are backed up inside the unit by internal batteries should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiating the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The raw data are then processed by the Test Risk Assessment Program (TRAP) software to produce detailed reports of the test results. Each of the TDAS Pro units are returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology.

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact.

ANTHROPOMORPHIC DUMMY INSTRUMENTATION

Use of a dummy in the 2270P vehicle is optional according to *MASH*, and there was no dummy used in the test.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

Photographic coverage of the test included three high-speed cameras: one overhead with a field-of-view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field-of-view parallel to and aligned with the installation at the downstream end. A flash bulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV video camera and still cameras were used to record and document conditions of the test vehicle and installation before and after the test.

TEST VEHICLE PROPULSION AND GUIDANCE

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2 to 1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time the vehicle's brakes were activated to bring it to a safe and controlled stop.

APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

Date: 2010-05-24 Test No.: 461430-1 VIN No.: 1D7HA18NIJJ564804

Year: 2005 Make: Dodge Model: Ram 1500 Quad-Cab Pickup

Tire Size: 245/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 105508

Note any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

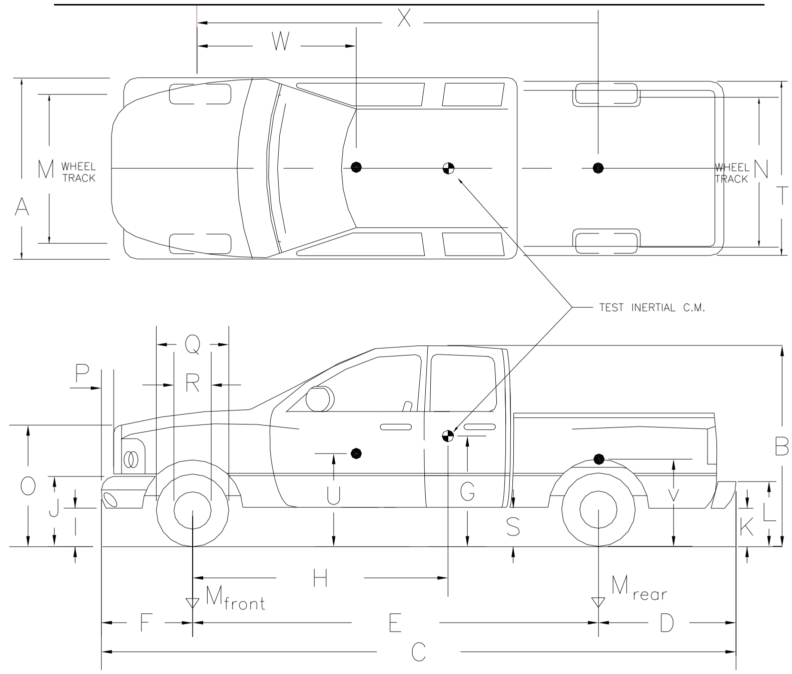
NOTES: ______

Engine Type: V8
Engine CID: 4.7 liter

Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD

Optional Equipment: ______

Dummy Data:
Type: No dummy
Mass: ______
Seat Position: ______



Geometry: inches

A	77.00	F	39.00	K	20.50	P	3.00	U	27.50
B	73.25	G	28.50	L	28.75	Q	29.50	V	33.00
C	227.00	H	63.11	M	68.25	R	18.50	W	59.50
D	47.50	I	13.50	N	67.25	S	14.25	X	140.50
E	140.50	J	26.00	O	44.75	T	75.50		

Wheel Center Ht Front	14.125	Wheel Well Clearance (FR)	6.125	Frame Ht (FR)	16.625
Wheel Center Ht Rear	14.125	Wheel Well Clearance (RR)	11.250	Frame Ht (RR)	24.250

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; M+N/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial		Gross Static	
Front	3650	M_{front}	2705	2754	Allowable		Allowable
Back	3900	M_{rear}	2086	2246	Range		Range
Total	6650	M_{Total}	4791	5000	5000 ±110 lb		5000 ±110 lb

Mass Distribution:
lb LF: 1400 RF: 1354 LR: 1101 RR: 1145

Figure 13. Vehicle Properties for Test No. 461430-1.

Table 2. Vehicle Center-of-Gravity Measurements for Test No. 461430-1.

Date: 2010-05-24 Test No.: 461430-1 VIN No.: 1D7HA18NIJJ564804

Year: 2005 Make: Dodge Model: Ram 1500 Quad-Cab Pickup

Body Style: Quad-Cab Mileage: 105508

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 255 +419 lb on top at front of bed (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 245/70R17

Measured Vehicle Weights: (lb)

LF:	1409	RF:	1353	Front Axle:	2762
LR:	1104	RR:	1153	Rear Axle:	2257
Left:	2513	Right:	2506	Total:	5019
					5000 ±110 lb allowed

Wheel Base: 140.5 inches Track: F: 68.25 inches R: 67.25 inches

148 ±12 inches allowed Track = (F+R)/2 = 67 ±1.5 inches allowed

Center of Gravity, SAE J874 Suspension Method

X: 63.18 in Rear of Front Axle (63 ±4 inches allowed)

Y: -0.05 in Left - Right + of Vehicle Centerline

Z: 28.5 in Above Ground (minumum 28.0 inches allowed)

Hood Height: 44.75 inches Front Bumper Height: 26 inches

43 ±4 inches allowed

Front Overhang: 39 inches Rear Bumper Height: 28.75 inches

39 ±3 inches allowed

Overall Length: 227 inches

237 ±13 inches allowed

Table 3. Exterior Crush Measurements for Test No. 461430-1.

Date: 2010-05-24 Test No.: 461430-1 VIN No.: 1D7HA18NIJJ564804

Year: 2005 Make: Dodge Model: Ram 1500 Quad-Cab Pickup

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	20	13	32	13	8	6.5	2.25	1	0.5	+11.5
2	Side plane above bump	NA	7	NA	NA	NA	NA	NA	NA	NA	NA
	Measurements recorded										
	in inches mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

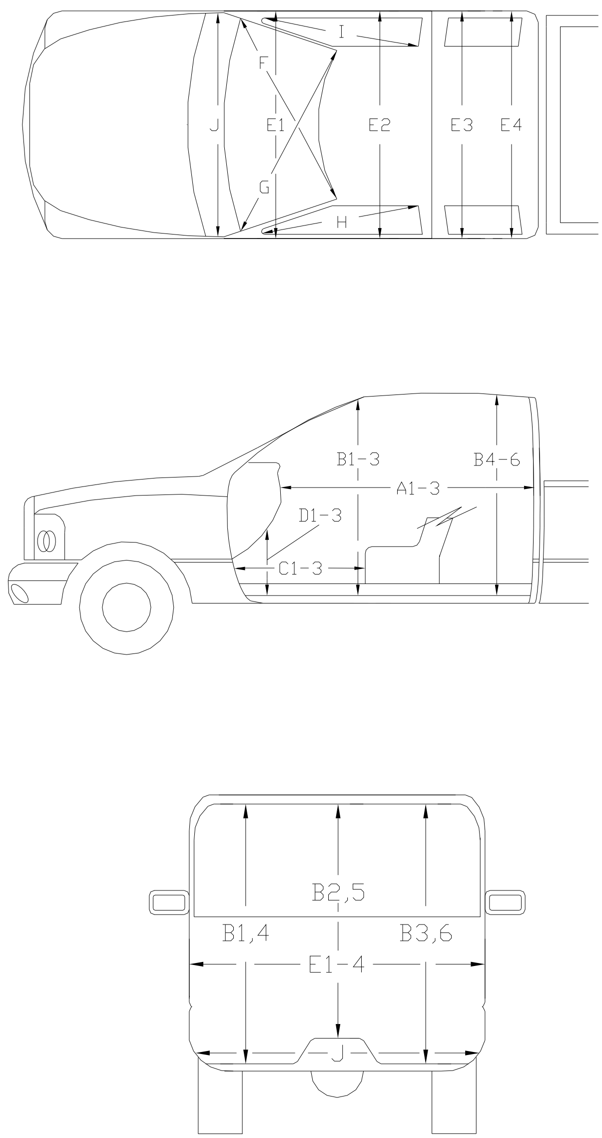
***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Table 4. Occupant Compartment Measurements for Test No. 461430-1.

Date: 2010-05-24 Test No.: 461430-1 VIN No.: 1D7HA18NIJJ564804

Year: 2005 Make: Dodge Model: Ram 1500 Quad-Cab Pickup



*Lateral area across the cab from
driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	64.75	64.50
A2	64.50	64.50
A3	65.25	65.25
B1	45.38	45.38
B2	39.25	39.25
B3	45.38	45.38
B4	42.25	42.25
B5	42.50	42.50
B6	42.25	42.25
C1	29.25	25.25
C2	-----	-----
C3	26.75	26.75
D1	12.75	12.25
D2	2.50	2.50
D3	11.62	11.62
E1	62.75	64.50
E2	64.25	64.50
E3	64.00	64.00
E4	64.12	64.12
F	60.00	60.00
G	60.00	60.00
H	39.75	39.75
I	39.75	39.75
J*	62.25	62.00

APPENDIX C. SEQUENTIAL PHOTOGRAPHS


0.000 s



0.050 s



0.100 s



0.150 s


Figure 14. Sequential Photographs for Test No. 461430-1 (Overhead and Frontal Views).

0.200s

0.250 s

0.350 s

0.400 s

Figure 14. Sequential Photographs for Test No. 461430-1 (Overhead and Frontal Views) (continued).

0.000 s

0.050 s

0.100 s

0.150 s

0.200 s

0.250 s

0.350 s

0.040

Figure 15. Sequential Photographs for Test No. 461430-1 (Rear of Barrier View).

APPENDIX D. VEHICLE ANGULAR DISPLACEMENTS AND ACCELERATIONS

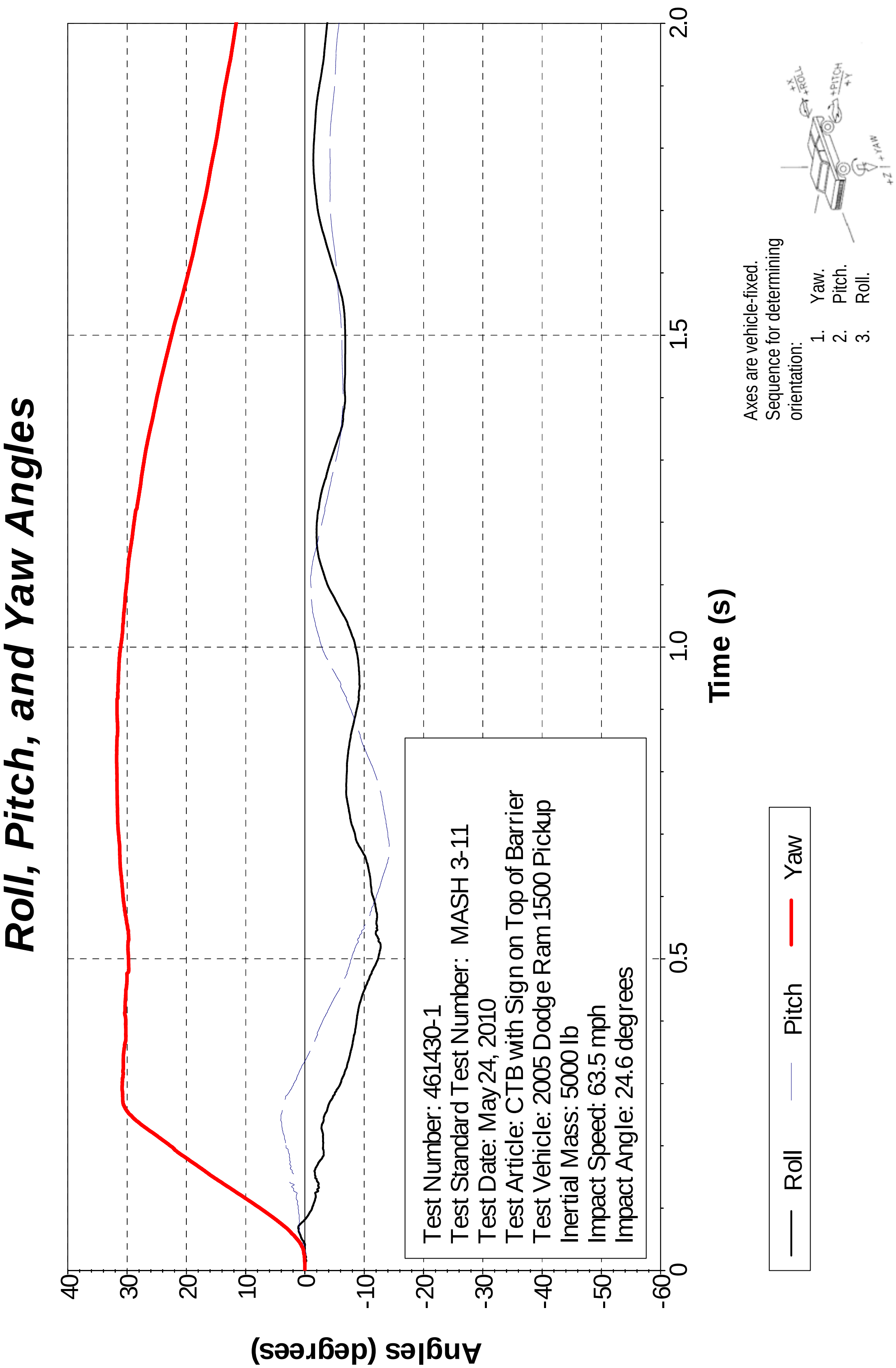


Figure 16. Vehicle Angular Displacements for Test No. 461430-1.

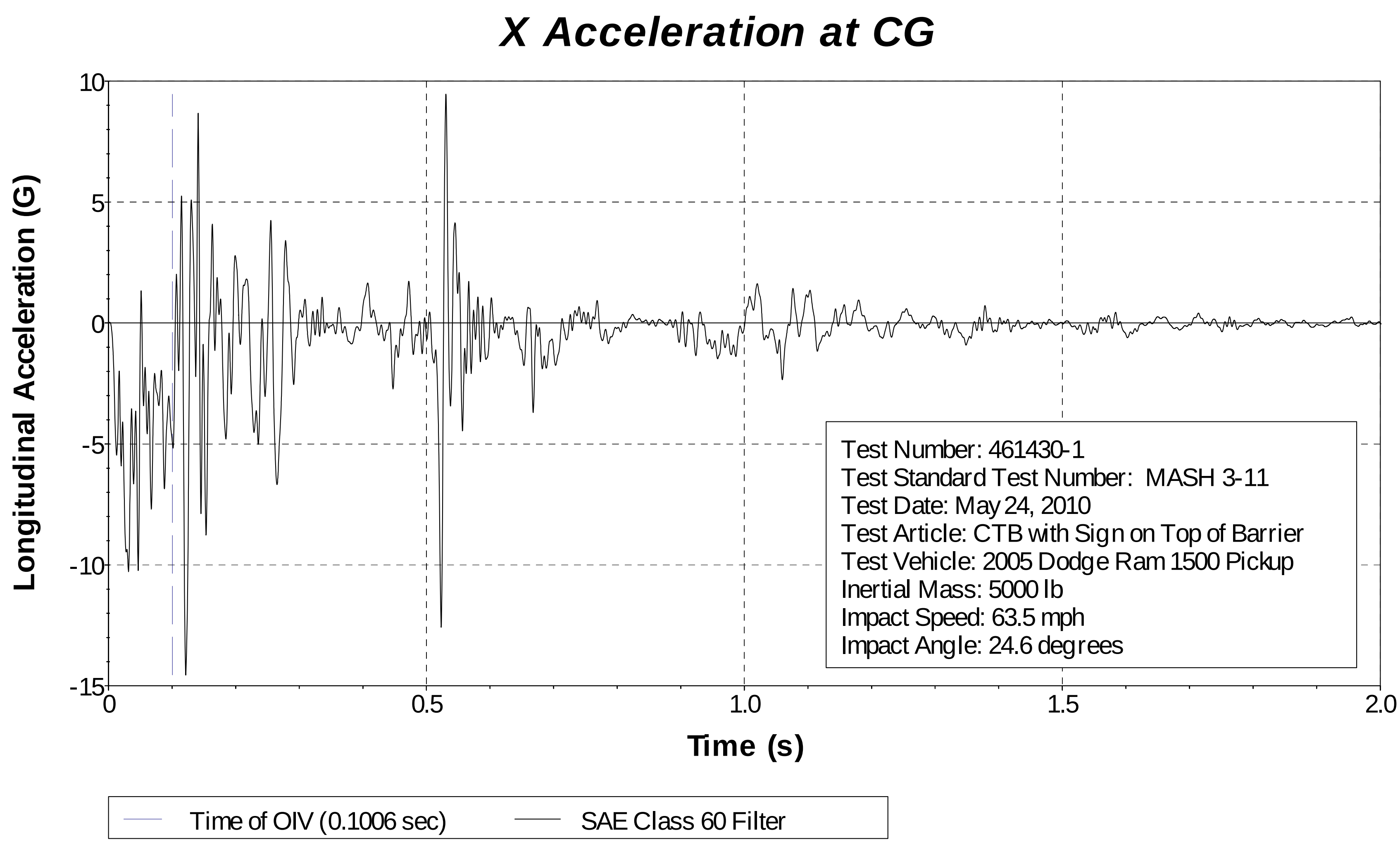


Figure 17. Vehicle Longitudinal Accelerometer Trace for Test No. 461430-1 (Accelerometer Located at Center of Gravity).

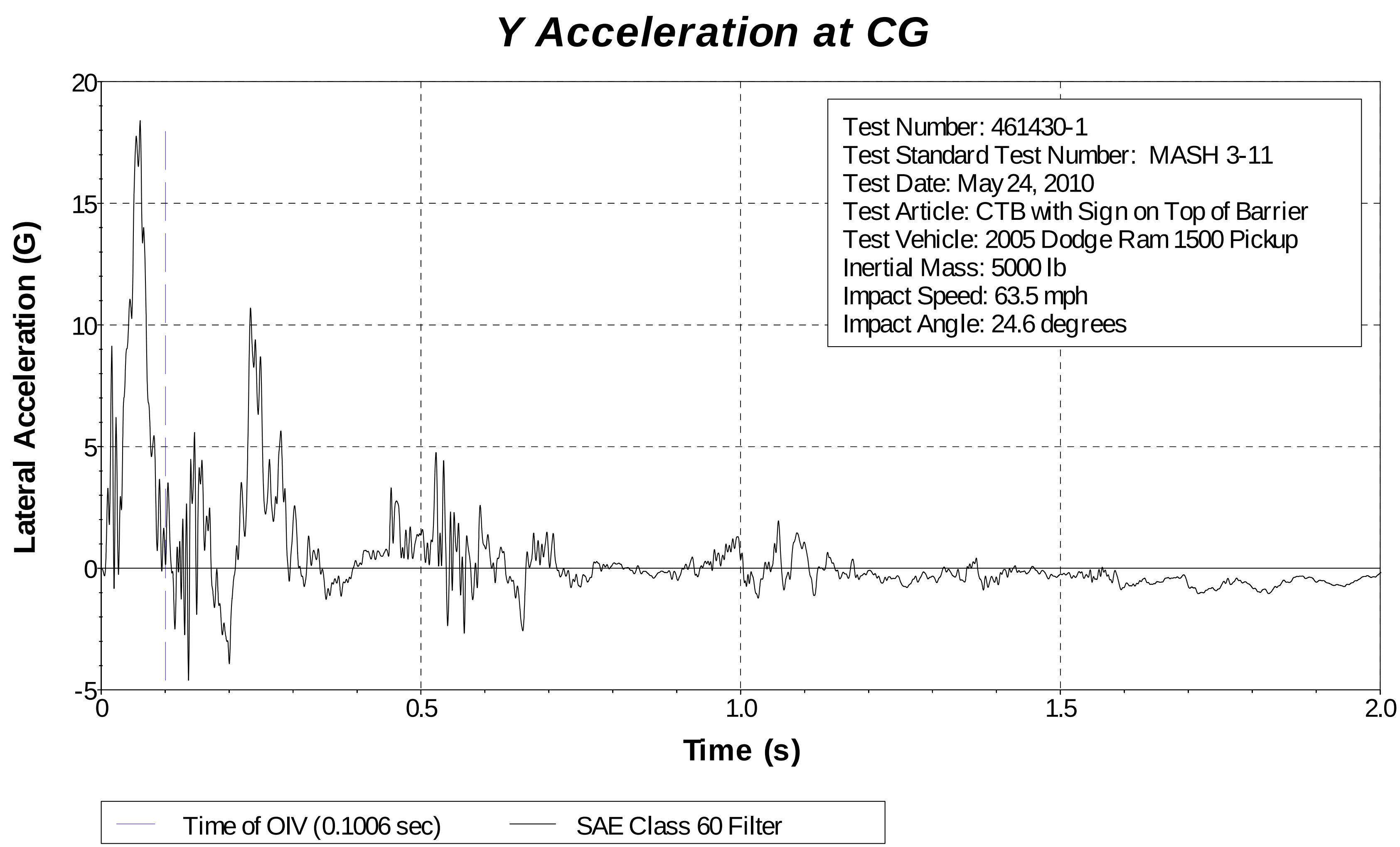


Figure 18. Vehicle Lateral Accelerometer Trace for Test No. 461430-1 (Accelerometer Located at Center of Gravity).

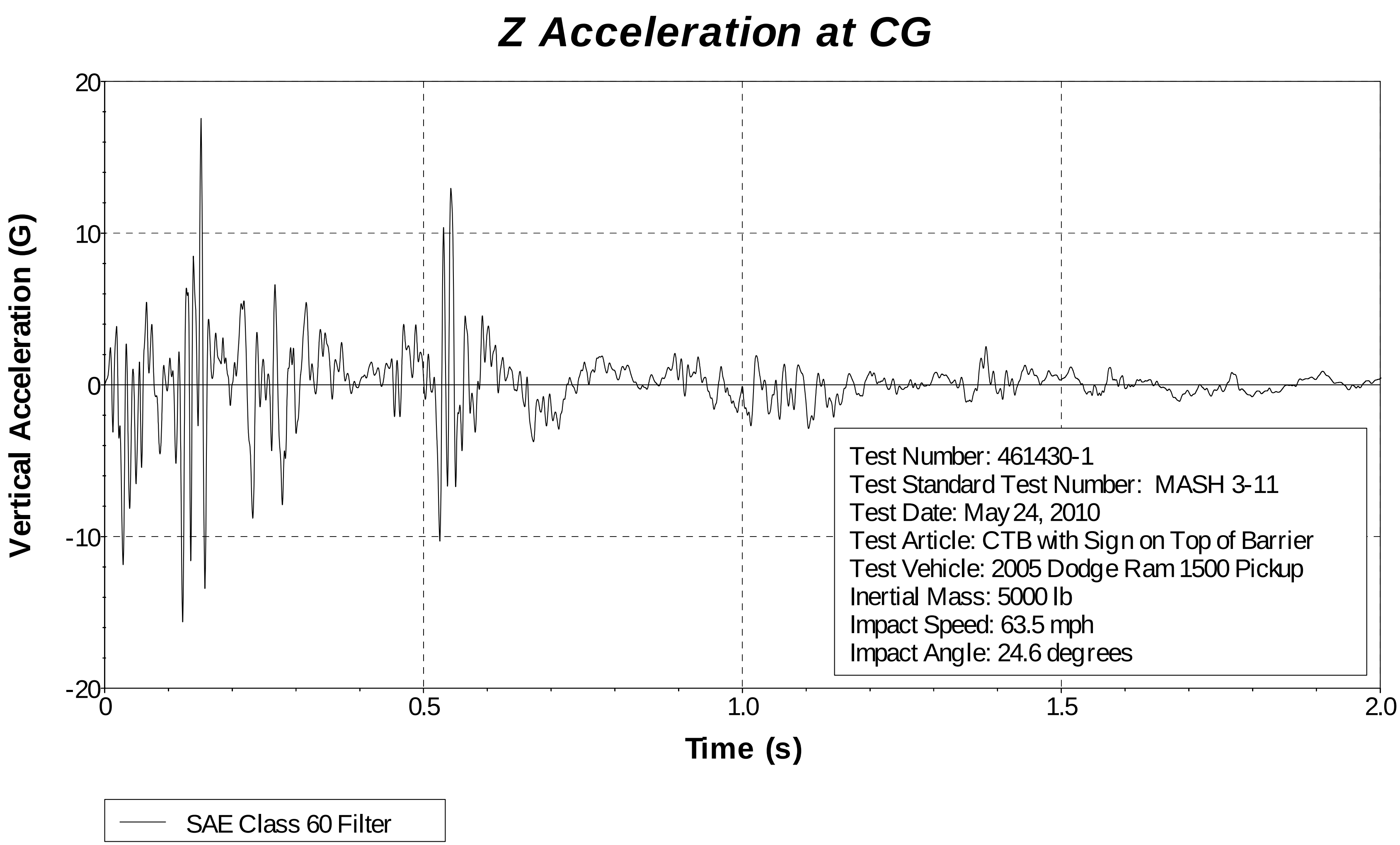


Figure 19. Vehicle Vertical Accelerometer Trace for Test No. 461430-1 (Accelerometer Located at Center of Gravity).

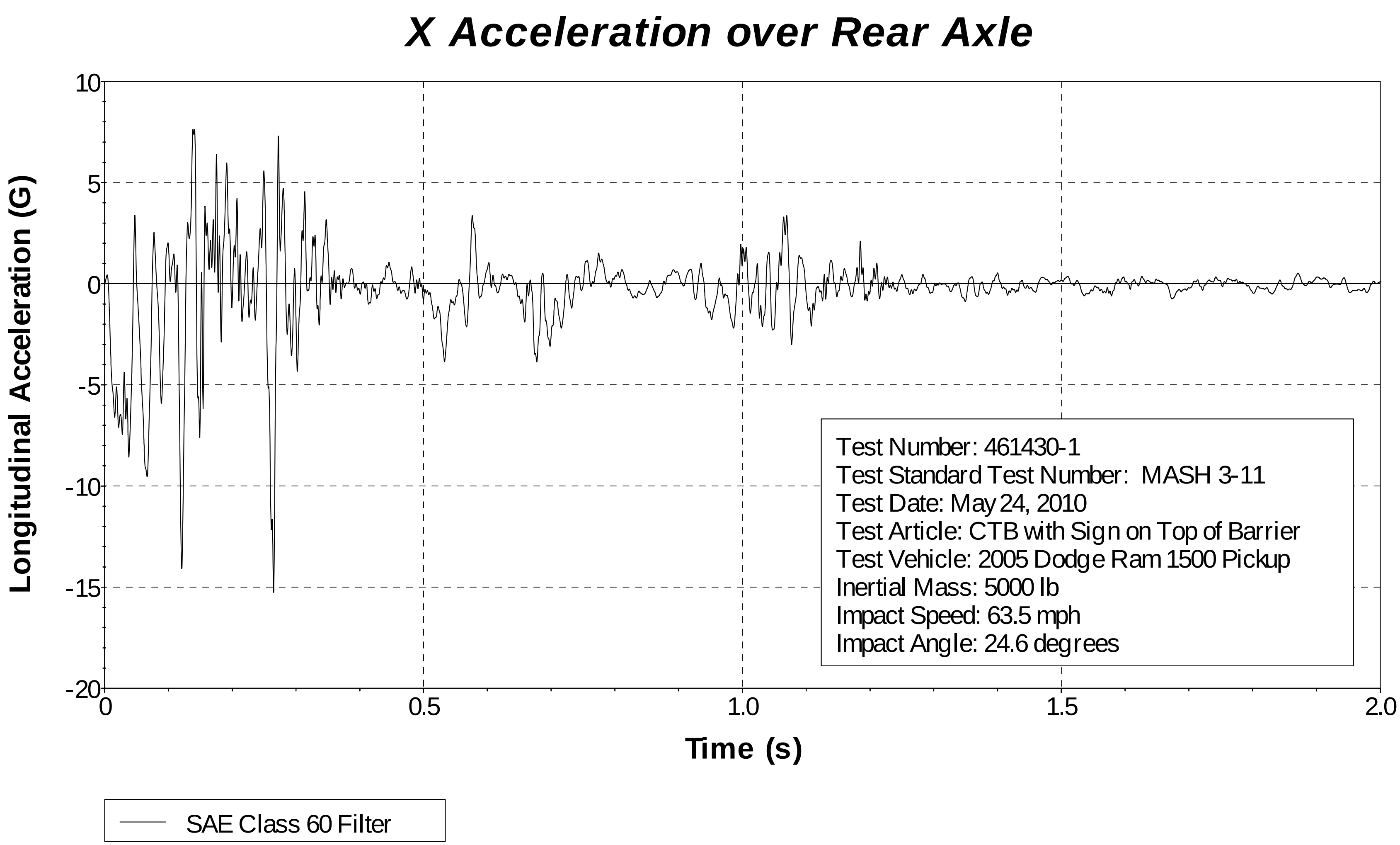


Figure 20. Vehicle Longitudinal Accelerometer Trace for Test No. 461430-1 (Accelerometer Located over Rear Axle).

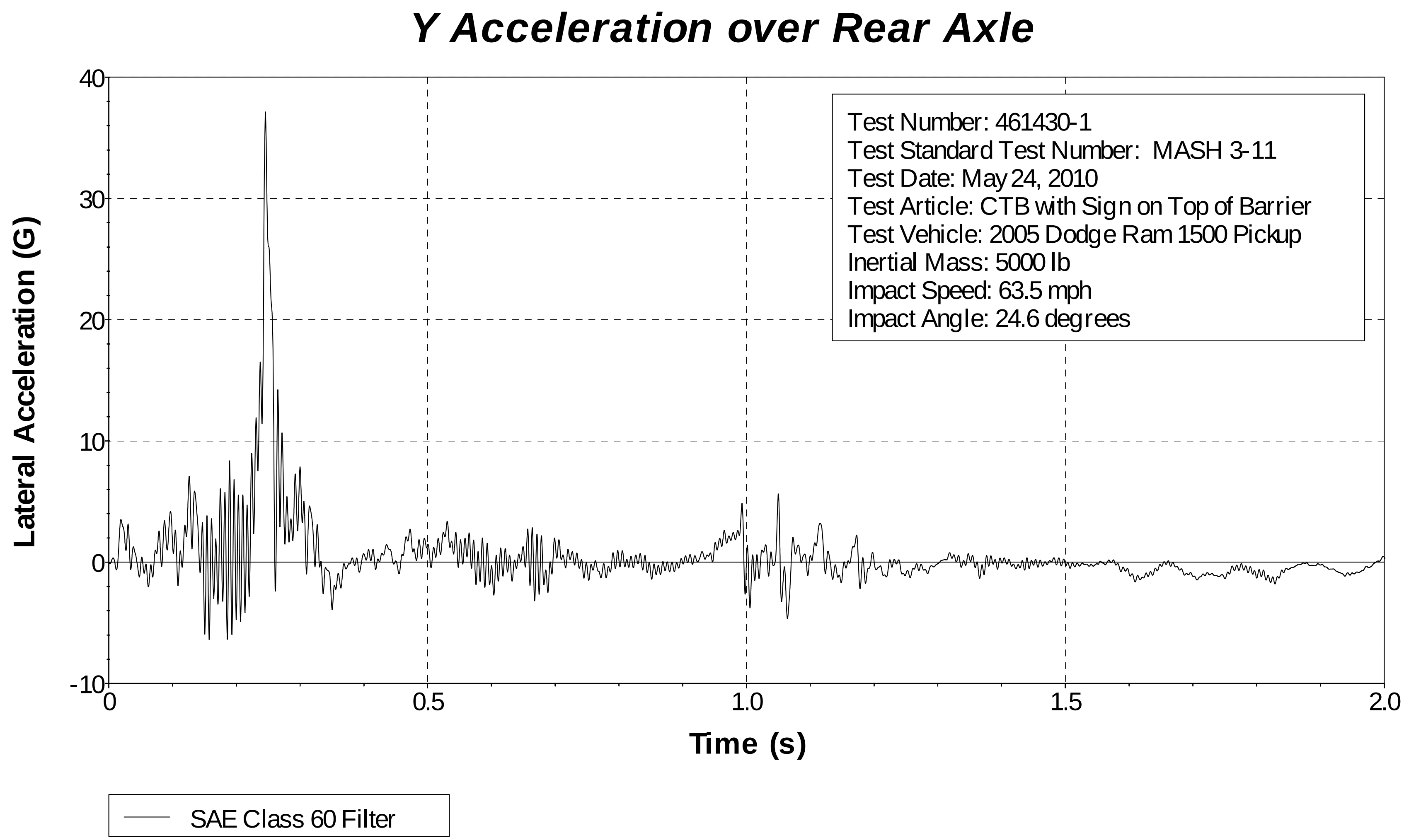


Figure 21. Vehicle Lateral Accelerometer Trace for Test No. 461430-1 (Accelerometer Located over Rear Axle).

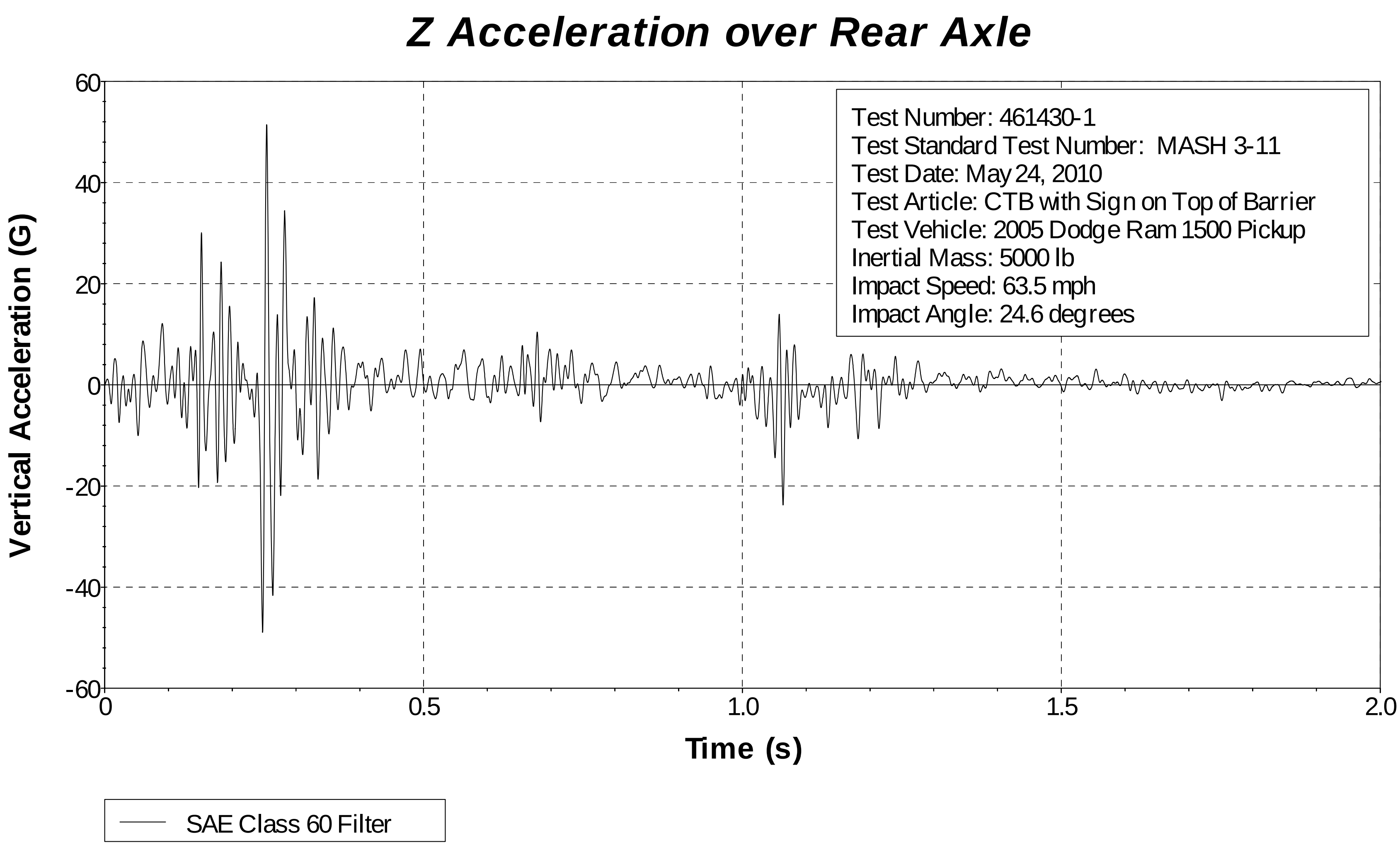


Figure 22. Vehicle Vertical Accelerometer Trace for Test No. 461430-1 (Accelerometer Located over Rear Axle).